

SLIDING MATERIAL MADE OF COPPER ALLOY,
METHOD OF PRODUCING SAME, SLIDING
BEARING MATERIAL, AND METHOD OF
PRODUCING SAME

BACKGROUND OF THE INVENTION

5 The invention relates to a copper-based sliding material in which the anti-seizure property and wear resistance thereof are enhanced by evenly dispersing hard substance particles, a method of producing the same, a sliding bearing and a method of
10 producing the same.

 As a copper-based sliding material, there is a bearing in which Kelmet is used. The Kelmet bearing is used as a sliding bearing for automobile engines etc. which sliding bearing is produced by the steps of
15 providing copper-lead-based sintered alloy layer bonded to a back metal of steel, and providing an overlay layer bonded to the surface of the copper-lead-based sintered alloy layer. In the Kelmet bearing, even in a case where the overlay layer is worn away, lead
20 contained in the copper-lead-based sintered alloy layer is fed to the sliding surface, so that good anti-seizure property is maintained.

 Namely, in conventional copper-based sliding materials represented by the Kelmet bearing, the anti-
25 seizure property is enhanced by adding lead (of about 20 mass%). However, since lead causes bad influence on the environment, it is preferred to reduce the content of lead as little as possible or not to use any lead.

On the other hand, since lead brings about the function explained above, the low content of lead makes the anti-seizure property deteriorated.

SUMMARY OF THE INVENTION

5 Recently, it is tried to enhance the anti-seizure property and the wear resistance by making fine, hard substance particles dispersed in copper matrix. However, the inventors of the invention have found out that, in a case where copper alloy powder and
10 fine, hard substance particles each having a size not more than 5 μm or not more than 10 μm are mixed in accordance with a powder-blending method to thereby provide a powder mixture and then the powder mixture is sintered, the hard substance particles 2 of much amount
15 come to exist in copper matrix 1 along the boundaries 3 defined by adjacent copper alloy grains, as shown in Fig. 6. When the hard substance 2 has low wettability relative to copper, the inventors of the invention have also found out that the bonding of the copper alloy
20 powder particles comes to be lowered, and that load applied from a counterpart shaft acts as shearing stress concentrated to the boundaries defined by the copper alloy grains adjacent to each other, so that there are such problems as premature breakage occurs
25 and as fatigue resistance becomes inferior.

The invention is achieved in view of the above situation, and the object of the invention is to

provide a copper-based sliding material having both of good anti-seizure property and superior resistance to fatigue without using any lead, a method of producing the same, a sliding bearing material, and a method of
5 producing the same.

According to a first aspect of the invention, there is provided a copper-based sliding material made of a copper-based, sintered alloy comprising sintered copper or sintered copper alloy, and 0.1 to 5 vol.%
10 hard substance particles harder in hardness than the copper or copper alloy, the hard substance particles being substantially evenly dispersed so that, when at least one, randomly selected surface portion or sectional portion of the sintered copper or sintered
15 copper alloy is partitioned into squares each having a side of 20 μ m, at least one of the particles exists in each of squares not less than 80% of the whole squares.

In the copper-based sliding material, since the fine, hard substance particles are evenly dispersed
20 in the copper or copper alloy, the anti-seizure property and the resistance to fatigue are enhanced. Further, since the hard substance particles are evenly dispersed in the copper or copper alloy without gathering at the boundaries of the grains of the copper
25 or copper alloy, load applied to the sliding material is dispersed with the result that the resistance to fatigue is enhanced. In a case where the amount of the hard substance particles is less than 0.1 vol.%, it

becomes impossible to obtain the effect of enhancing both of the anti-seizure property and the resistance to fatigue, and in another case where the amount of the hard substance particles is more than 5 vol.%, the hard substance particles cause bad influence on the resistance to fatigue and enlarges the attacking on a counterpart member.

According to a second aspect of the invention, there is provided a method of producing the copper-based sliding material, in which method both of the copper powder or copper alloy powder and the powder of the hard substance harder in hardness than the copper or copper alloy are treated by use of a mechanical alloying method, so that it becomes possible to produce composite powder having such structure as the hard substance particles are dispersed evenly in each particle of the copper or copper alloy powder. By sintering this composite powder prepared through the mechanical alloying method to thereby produce the copper-based sliding material, it becomes possible to readily produce the copper-based sliding material in which the hard substance particles are evenly dispersed in the copper or copper alloy.

According to a third aspect of the invention, there is provided a sliding bearing material in which the copper-based sliding material according to the first aspect of the invention is bonded to a back metal, whereby it becomes possible for the sliding

bearing material to have superior load-carrying capacity and superior resistance to fatigue.

According to a fourth aspect of the invention, there is provided a sliding bearing material
5 having a three-layers structure, which sliding bearing material comprises a back metal, an intermediate layer made of copper or copper alloy which layer is bonded to the back metal, and a layer of the copper-based sliding material according to the first aspect of the invention
10 bonded onto the intermediate layer, the copper-based sliding material layer which is an uppermost layer being provided with a thickness not less than 0.05 mm.

In this constitution, the bonding strength between the back metal and the copper-based sliding
15 material layer can be enlarged by the intermediate layer interposed therebetween. Further, by thinning the thickness of the copper-based sliding material layer to thereby reduce the amount of the use thereof in view of the high production cost of the powder
20 prepared by the mechanical alloying method, it becomes possible to reduce the production cost of the sliding bearing material. As regards the thickness of the copper-based sliding material layer, a thickness not less than 0.05 mm is required to maintain such effect
25 as to enhance the anti-seizure property and the wear resistance.

According to a fifth aspect of the invention, there is provided a method for producing the sliding

bearing material, in which method both of the copper or copper alloy powder and the hard substance powder harder in hardness than the copper or copper alloy are treated by the mechanical alloying process to thereby
5 provide composite powder, by using which composite powder is formed the copper-based sliding material layer on the intermediate layer, so that it becomes possible to readily produce the sliding bearing material of three-layer structure at a low cost.

10 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic drawing depicted from the microstructure of the copper-based sliding material according to one embodiment of the invention.

Fig. 2 is a schematic drawing depicted from
15 the microstructure of the composite powder for sintering which is produced by the mechanical alloying method.

Fig. 3 is a sectional drawing of a half bearing.

20 Fig. 4 is a graph showing the results of the seizure test.

Fig. 5 is a graph showing the results of the fatigue test.

Fig. 6 is a drawing corresponding to Fig. 1
25 regarding the copper-based sliding material powder produced by the powder-blending method.

DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE
INVENTION

One embodiment of the invention is described below while referring to Figs. 1 to 5.

5 A bearing 11 shown in Fig. 3 is called a half bearing, two pieces of which are paired to be used as a sliding bearing for automobile engines etc. This bearing 11 comprises a back metal 12 formed of, for example, a thin steel sheet, an intermediate layer 13
10 bonded to the back metal which intermediate layer is the plating layer or sintered layer of copper or copper alloy, the layer 14 of a copper-based sliding material related to the invention which layer is bonded to the intermediate layer, and an overlay layer 15 made of a
15 soft metal or resin which overlay layer is bonded to the copper-based sliding material layer 14.

The copper-based sliding material layer 14 is made of a copper-based sintered alloy, which contains 0.1 to 5 vol.% hard substance particles of carbide such
20 as, for example, WC or Al_2O_3 , in copper or copper alloy matrix which hard substance particles are harder in hardness than the copper or copper alloy matrix. In addition, in the copper-based sliding material layer (copper-based sintered alloy) 14, the hard substance
25 particles 17 are evenly dispersed in the copper or copper alloy matrix 16, as shown in Fig. 1. In Fig. 1, the matrix 16 is shown as a white color portion, and the hard substance particles 17 are shown as black

color dots or points.

In this case, the degree of the even dispersion of the hard substance particles 17 is such that, when at least one, randomly selected surface
5 portion or sectional portion of the sintered copper-based sliding material layer 14 is partitioned into squares each having a side of $20\ \mu\text{m}$, at least one of the particles 17 exists in each of squares not less than 80% of the whole squares.

10 In this embodiment, a rectangular or square area not less than $0.01\ \text{mm}^2$ was selected regarding one randomly selected portion of the sintered copper-based sliding material layer 14, and this area was partitioned into a plurality of squares (, that is, not
15 less than 25 pieces of squares) each having a side of $20\ \mu\text{m}$ in order to estimate the degree of the even dispersion of the hard substance particles 17. As the result thereof, at least one of the hard substance particles 17 existed in each of squares not less than
20 80% of the whole squares. When providing the square partitions each having a side of $20\ \mu\text{m}$, a plurality of portions spaced apart from each other may be randomly selected, in each of which portions one partition may be provided or in each of which portions a plurality of
25 partitions may be provided. In other words, the degree of the even dispersion of the hard substance particles was such that at least one of the hard substance particles existed in each of not less than 80% pieces

of the total partitions selected randomly in the above-explained manner.

In addition to WC and Al_2O_3 , the hard substance may be at least one selected from the
5 following substances:

borides ---- NiB , Ni_3B , CrB_2 , CrB , ZrB_2 , CoB ,
 TiB_2 , VB_2 , TaB_2 , WB , MoB , Fe-Bb based substances and
etc.;

silicides--- $TiSi_2$, WSi_2 , $MoSi_2$, $TaSi_2$, $CrSi_2$,
10 Fe-Si based substances, Mn-Si based substances, and
etc.;

oxides ----- SiO_2 , TiO_2 , ZrO_2 , WO_3 , MoO_3 , Mn-O
based substances, Fe-O based substances, V-O based
substances and etc.;

15 nitrides --- Si_3N_4 , TiN , ZrN , TaN , VN , AlN ,
c-BN, Cr_2N and etc.;

carbides --- Mo_2C , W_2C , SiC , B_4C , TiC , TaC , VC ,
 ZrC and etc.;

intermetallic compounds --- Ni-Sn based
20 substances, Fe-W based substances, Fe-Mo based
substances, Fe-Mn based substances, Fe-Cr based
substances, Fe-Al based substances, Cr-Al based
substances, V-Al based substances, Ti-Al based
substances, W-Al based substances and etc.;

25 metals ----- W, Mo and etc.; and

other hard substances --- Ni-based, self-
fluxing alloys (such as Ni-B-Si based alloys), Co-
based, self-fluxing alloys (such as Co-Mo-Cr-Si-B based

alloys) and etc.

Then, a method of producing the half bearing 11 is described below.

First, both of copper or copper alloy powder
5 and the powder of the hard substance were treated by the
mechanical alloying method to thereby obtain composite
powder in which hard substance particles were evenly
dispersed in each particle of the copper or copper alloy
powder. By performing the treatment through the
10 mechanical alloying method, the copper or copper alloy
powder were subjected to the repetition of pressure
bonding and pulverizing, so that each of the hard
substance particles was contained in the interior of
each of the powder particles of the copper or copper
15 alloy. As the result thereof, the treated powder of the
copper or copper alloy became composite powder particles
18 each having the hard substance particles 17 evenly
dispersed in the interior thereof, as shown in Fig. 2.
In Fig. 2, portions depicted by oblique lines indicate
20 resin used for fixing the powder particles 18.

On the other hand, to provide the
intermediate layer 13, copper or copper alloy plating
was provided on the steel sheet used for the back
metal 12, or copper or copper alloy powder was spread
25 onto the steel sheet. Then, the powder 18 obtained
above was spread onto the copper or copper alloy
plating or the powder layer provided on the steel
sheet, and they were sintered at a temperature of 800

to 920°C for about 15 minutes and then were rolled. Further, in order to enhance the density thereof, the sintering and the rolling thereof were repeated, whereby a bimetal was produced in which a copper-based sliding material layer 14 is bonded to the steel sheet through the intermediate layer 13. Alternatively, the powder 18 may be spread directly on the steel sheet to thereby provide the copper-based sliding material layer 14 without interposing the intermediate layer 13 between them. After thus producing the bimetal, the bimetal was cut into a predetermined width and a predetermined length, and the cut bimetal was bent to have a semi-cylindrical shape with the surface of the sliding material layer 14 being finished by machining. After that, the overlay layer 15 was bonded onto the sliding material layer 14.

Thus, the half sliding bearing 3 shown in Fig. 3 was formed. Two pieces of the half bearing 11 are butted to form a sliding bearing having a cylindrical shape, which sliding bearing can be used as a main bearing supporting a crank shaft for automobile engines or as a connecting-rod bearing.

Regarding the products embodying the invention and comparative products each of which was made of the powder having the compositions "A" and "B" shown in Table 1 in compliance with the manner described above, the inventors of the invention performed seizure test, fatigue test, and bonding test,

the results of each of the tests being shown in Table 1, and in Figs. 4 and 5. In Table 1, the composition "A" is the composition of the copper or copper alloy, the composition "B" being that of the hard substance particles, the composition "C" being that of the intermediate layer 13.

In the seizure test, a rotating shaft driven by a motor was supported by a bearing similar to that of Fig. 3 (, which bearing is, however, provided with no overlay layer 15 in order to more clearly observe the characteristics of the copper-based sliding material 14), and the running-in was performed in the initial period of 60 minutes. Thereafter, the feed rate of the lubricant was reduced to stepwise raise 5 MPa by 5 MPa the specific load of the bearing, the driving being performed for 10 minutes per each of the specific loads of the bearing. In this test, a specific load lower by one step than the specific load of the bearing measured at the time when the temperature of the back face of the bearing exceeded 220°C or when the driving current of the motor driven to rotate the rotating shaft came to have an abnormal value was deemed to be the maximum specific load with no seizure. Other test conditions are shown in Table 2.

In the fatigue test, only a small piece of the copper-based sliding material 14 was used, and a test load was applied onto the small piece. The test

load was raised stepwise 10 MPa by 10 MPa from the initial test load of 50 MPa, the test load being applied 50,000 times per each test load in a sine-wave manner, and the test load at the time when a crack
5 occurred in the small piece was deemed to be the fatigue breakage load.

The bonding test was performed to examine the bonding strength obtained between the back metal and the layer 14 of the copper-based sliding material (or
10 the intermediate layer 13), in which bonding test a tensile force was applied in a direction along the bonding interface defined between the back metal 12 and the copper-based sliding material 14, and a tensile stress at the time when the layer of the copper-based
15 sliding material was peeled off from the back metal was deemed to be the bonding strength.

Table 1

	No.	copper-based sliding material layer										intermediate layer		bonding strength N/mm ²
		composition "A" (mass%)						composition "B" (vol%)		thickness (mm)	composition "C" (mass%)	thick-ness (mm)		
Embodiment Products	1	the balance	6	1.5	-	-	-	1.5	-	0.4	-	-	280	
	2	the balance	6	1.5	-	-	-	1.5	-	0.2	Cu-6 Sn-1.5Ni	0.2	300	
	3	the balance	-	-	-	-	-	-	3	0.4	-	-	190	
	4	the balance	-	-	-	-	-	-	3	0.2	Cu-10 Sn	0.2	260	
	5	the balance	-	2	-	-	-	-	1	0.4	-	-	230	
	6	the balance	-	2	-	-	-	-	1	0.2	Cu-10 Sn	0.2	260	
	7	the balance	3	1.5	-	-	-	2	-	0.4	-	-	240	
	8	the balance	10	-	-	-	5	1.5	-	0.4	-	-	220	
Comparative Products	1	the balance	-	-	-	-	-	-	-	0.4	-	-	200	
	2	the balance	6	1.5	-	-	-	-	-	0.4	-	-	300	
	3	the balance	6	1.5	-	-	-	1.5	-	0.4	-	-	210	
	4	the balance	-	-	-	-	-	-	6	0.4	-	-	150	
	5	the balance	3.5	-	23	-	-	-	-	0.4	-	-	140	

Table 2

Item	Condition
diameter of shaft	53 mm
width of bearing	13 mm
peripheral speed	10 m/sec.
lubricant	SAE #20
feed rate of lubricant	12.5 ml/minute
material of shaft	JIS-S55C as quenched product
shaft roughness	not more than R max 1.0 μ m

Specific method for producing the embodiment
5 bimetal products Nos. 1 to 8 and the comparative
bimetal products Nos. 1 to 5 are described below.

"Products Nos. 1 to 8 Embodying the Invention"

Both of the atomized powder of the
composition "A" having a particle size not more than
10 250 μ m (, however, in each of the products Nos. 3 and 4
electrolytic powder was used) and the particles of the
composition "B" having the average particle size of 1
 μ m were treated for 50 hours by the mechanical alloying
method disclosed in JP-A-4-28802, so that a composite
15 powder was produced in which the particles (each having
a size of about 1 to about 6 μ m) of the composition "B"
are substantially evenly dispersed in each particle
(having a size not more than 300 μ m) of the powder of

the composition "A". This composite powder was spread directly on the steel sheet in the case of the embodiment products Nos. 1, 3, 5, 7, and 8 (, that is, the steel sheet was provided with no intermediate layer 5 13). In the case of the embodiment products Nos. 2, 4, and 6, the powder of the composition "C" and the mixture powder were spread in this order on the steel sheet (, that is, an intermediate layer 13 was provided). After that, both of the sintering and the 10 rolling thereof were repeated two times, whereby the bimetal products were produced.

"Comparative Products Nos. 1, 2 and 5"

Each of comparative bimetal products Nos. 1, 2 and 5 were produced by the steps of spreading on the 15 steel sheet the atomized powder of the composition "A" having the particle size not more than 250 μm (, however, in comparative product No. 1 electrolytic powder was used), and repeating two times both of the sintering and rolling thereof.

20 "Comparative Product No. 3"

Comparative bimetal product No. 3 was produced by the steps of mixing for one hour both of the atomized powder of the composition "A" having a particle size not more than 250 μm and the particles of 25 the composition "B" having an average particle size of about 1 μm by use of a conventional powder-blending

method to thereby produce a mixture powder, spreading this mixture powder on the steel sheet, and repeating two times both of the sintering and rolling thereof.

"Comparative Product No. 4"

5 Comparative bimetal product No. 4 was produced by the steps of treating by use of the mechanical alloying method for 50 hours both of the electrolytic powder of the composition "A" having a particle size not more than 250 μm and the particles of
10 the composition "B" having an average particle size of about 1 μm to thereby produce a composite powder in which the particles of the composition "B" were evenly dispersed in each of the powder particles of the composition "A", spreading this mixture powder on the
15 steel sheet, and repeating two times both of the sintering and rolling thereof.

The analysis of the test results regarding the above bimetal products is described below.

First, on the surface of each of the
20 embodiment products Nos. 1 to 8 and the comparative product No. 3, partitions each having a square shape having an area of 0.01 m^2 were formed at a randomly selected surface portion so that each of the partitions had one side of 20 μm and so that 25 pieces of the
25 partition were provided, and regarding these partitions the dispersion of the hard substance particles each having a size of about 1 to about 6 μm was examined.

As the result thereof, in each of the embodiment product Nos. 1 to 8, at least one of the hard substance particles existed in each of the partitions of 92 to 100% of the whole partitions. On the other hand, in 5 the comparative product No. 3, at least one of the hard substance particles existed in each of the partitions of 60% of the whole partitions. Fig. 1 shows the dispersion of the hard substance particles 17 regarding the embodiment product No. 1.

10 The comparative product No. 5 contains much amount of lead of about 23 mass%, which product corresponds to the conventional Kelmet bearing. In comparing the embodiment products Nos. 1 to 8 with the comparative product No. 5, although the anti-seizure 15 property of each of the embodiment products Nos. 1 to 8 is equivalent to or more than that of the comparative product No. 5, the resistance to fatigue of each of the embodiment products Nos. 1 to 8 is remarkably enhanced in comparison with that of the comparative product No. 20 5 because each of the products Nos. 1 to 8 contains no Pb which is a soft metal.

 The reason why the superior anti-seizure property is brought about in spite of no lead in each of the products Nos. 1 to 8 is that the hard substance 25 particles 17 harder in hardness than the matrix 16 are evenly dispersed and that the hard substance particles become convex in shape relative to the matrix 16 to thereby come to be in lapping contact with a

counterpart shaft.

The load of the counterpart shaft is carried by the hard substance particles directly contacting with the shaft. The load applied to the hard substance particles 17 functions as shearing stress exerted to the boundary defined between the hard substance particles 17 and the matrix 16 surrounding the hard substance particles. However, since the hard substance particles 17 are fine in size and are dispersed in such an even, high density state as at least one of the hard substance particles 17 exists in a square partition having one side of about 20 μm at a probability of 80% or more, a load portion which is applied to one of the hard substance particles 17 becomes small, so that there occurs no fear that any crack is caused at the boundary, whereby the resistance to fatigue of each of the products Nos. 1 to 8 is enhanced.

The embodiment product No. 1 differs from the comparative product No. 3 in the respect of whether or not the compositions "A" and "B" are treated by the mechanical alloying method, that is, whether or not the hard substance particles 17 are evenly dispersed. In comparing the embodiment product No. 1 with the comparative product No. 3, the anti-seizure property of the embodiment product No. 1 is slightly higher than that of the comparative product No. 3, however, the resistance to fatigue of the embodiment product No. 1 is remarkably superior to the comparative product

No. 3. Thus, it is appreciated that the even dispersing of the hard substance particles 17 is effective to enhance the anti-seizure property and in particular the resistance to fatigue.

5 In a case where the content of the hard substance particles 17 exceeds 5 vol.%, they cause bad influence particularly on the anti-seizure property. For example, the embodiment product No. 3 differs from the comparative product No. 4 in that the former
10 contains the hard substance particles 17 of 3 vol.% while the latter contains that of 6 vol.%. The comparative product No. 4 containing the much amount of the hard substance particles 17 has the resistance to fatigue substantially equivalent to that of the
15 embodiment product No. 3, however, the anti-seizure property of the comparative product No. 4 is very inferior to that of the embodiment product No. 3.

 In each pair of the embodiment products Nos. 1 and 2, the embodiment products Nos. 3 and 4, and the
20 embodiment products Nos. 5 and 6, the former differs from the latter in that the former has no intermediate layer 13 with the copper-based sliding material layer 14 being made to have such a large thickness as to be about 0.4 mm while the latter has an intermediate layer
25 13 and the copper-based sliding material layer 14 made to have such a thin layer as to be about 0.2 mm in thickness. Regarding each of the anti-seizure property and the resistance to fatigue, the former embodiment

products Nos. 1, 3 and 5 are equivalent to the latter
embodiment products Nos. 2, 4 and 6, respectively.

However, the latter embodiment products Nos. 2, 4 and 6
each provided with the intermediate layer 13 have the
5 enhanced bonding strengths in comparison with that of
the former embodiment products Nos. 1, 3 and 5,
respectively.

Thus, even in a case where the intermediate
layer 13 is provided while the thickness of the copper-
10 based sliding material layer 14 is reduced by the value
corresponding to the thickness of the intermediate
layer 13, it becomes possible to obtain the products
superior regarding each of the bonding strength, anti-
seizure property and the resistance to fatigue.
15 Therefore, it becomes possible to reduce the amount of
the expensive powder treated by the mechanical alloying
method, so that the sliding bearing can be produced
with a relatively low cost.

The invention is not limited to the products
20 of the embodiments and/or the drawings but can be
extended to or can be changed to the case described
below.

In a case of a hard substance having good
wettability relative to the copper or copper alloy, the
25 powder of this hard substance and the powder of the
copper or copper alloy may be mixed with each other by
use of a usual powder-blending method without using any
mechanical alloying method. Further, the intermediate

layer 13 may be provided with a multi-layer structure
in which copper or copper alloy is coated on a copper-
plated steel sheet. The copper-based sliding material
can be used not only for bearings but also for other
5 sliding materials.